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UNITED STATES DEPARTMENT OF AGRICULTURE

Diseases of Dent Corn in the United States[1]

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Corn diseases annually reduce the corn production of the United States many million bushels. The losses in individual fields often exceed 10 percent. The diseases also lower the value and quality of the grain and fodder and increase the cost of harvesting when they cause the crop to lodge. In the United States corn is subject to about 25 diseases. These attack all parts of the plant—the ears, leaves, stalks, and roots—at various stages of development. Many of them are present wherever corn is grown, but the relative importance of the diseases varies in different sections of the country.

In this circular all of the major and some of the more conspicuous minor corn diseases in the United States are considered. The outstanding symptoms, together with control measures so far as they are known, are described, and the geographic distribution and relative economic importance of each disease are discussed. For the reader's convenience the diseases are grouped according to the part of the plant they attack.

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[1] Cooperative investigations of the Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, and the Department of Botany of the Purdue University Agricultural Experiment Station, Lafayette, Ind.

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The most important means of controlling corn diseases is by growing resistant hybrids, where they are available. Additional measures involve the use of sound seed, seed treatment, and proper rotational and cultural practices.

NATURE OF CORN DISEASES

The diseases of dent corn, like those of any other plant, are influenced by three very important factors: (1) The disease-producing agent, which may be a fungus, a bacterium, or a virus; (2) the environmental conditions, which include the temperature and humidity of the atmosphere, the temperature and moisture of the soil, and the various aspects of soil fertility; and (3) the host plants, which may differ in their heritable resistance to disease, depending on the particular variety or hybrid. All these play important roles and act together in determining the severity of corn diseases. A thorough knowledge of all the aspects of these factors is essential to a proper understanding of the nature and control of corn diseases.

Disease-Producing Organisms

Each infectious disease of corn is caused by a specific organism. Only the diseases caused by fungi and bacteria will be considered in detail, as they are of greatest importance in the United States. Fungi or molds and bacteria are microscopic organisms of various sizes and shapes (fig. 1) which gain entrance into the plant through natural openings or wounds or by direct penetration. Once within the plant, they become parasitic and absorb food materials, secrete toxic substances, plug the water-conducting vessels, or otherwise interfere with the normal functioning of the host. This weakens the plant and may eventually kill it. Disease-producing parasites may live over from one growing season to the next on plant refuse in the field, in the soil, on seeds, and in some instances in the bodies of hibernating insects. Spread of these organisms may be accomplished by various agencies, such as wind currents, water, seeds, or insects.

Environment

It is a common observation that environmental conditions vary in different localities and in different seasons. Such variations are responsible for differences in disease development that are so frequently seen. One set of conditions may favor the progress of one or more diseases and not others. Unfortunately, many corn diseases may develop best under conditions that are ideal for growth of the corn plant. Seedling diseases, on the other hand, are generally most severe when the soil is cold and wet.

The Host Plant

The inherent resistance or susceptibility of a corn hybrid or variety may frequently determine the severity of disease development. It is in the use of resistant varieties and hybrids that the grower may find the most efficient and practical method for controlling corn diseases. A given hybrid or variety may not be inherently resistant to all

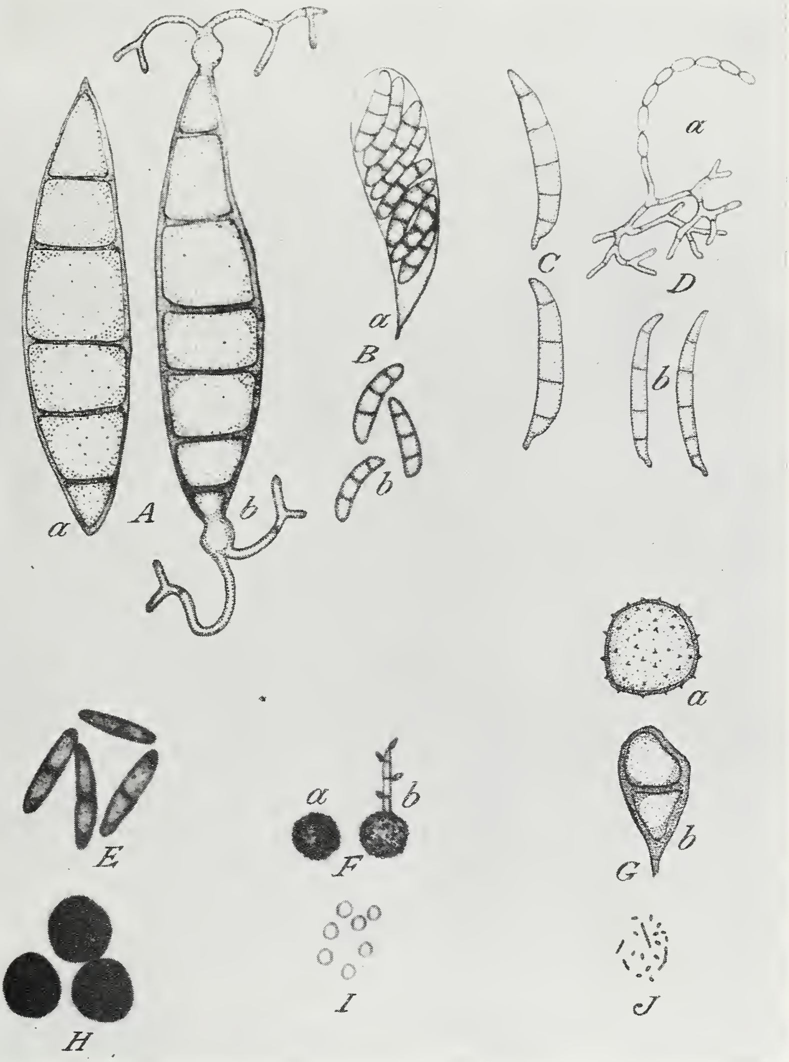

FIGURE 1.—Various types of spores and cells of some of the fungi and bacteria known to cause diseases of corn. *A*, Spores of *Helminthosporium turcicum* Pass.; *a*, ungerminated spore, *b*, germinating spore. *B*, *a*, Spore-sac or ascus of the fungus *Gibberella zeae* (Schw.) Petch, *b*, ascospores free of the ascus. *C*, Conidiospores of *G. zeae*. *D*, Two kinds of spores of *Gibberella fujikuroi* (Saw.) Wr. (*Fusarium moniliforme* Sheld.); *a*, microconidia, *b*, macroconidia. *E*, Spores of *Diplodia zeae* (Schw.) Lév. *F*, Spores of the common smut fungus *Ustilago maydis* (DC.) Cda.; *a*, ungerminated spore, *b*, germinated spore. *G*, Spores of the corn rust fungus *Puccinia sorghi* Schw.; *a*, red summer spore or urediospore, *b*, black winter spore or teliospore. *H*, Spores of *Nigrospora sphaerica* (Sacc.) Mason (*Basisporium gallarum* Moll.). *I*, Spores of *Penicillium* species. *J*, Cells of bacterial wilt bacteria, *Aplanobacter stewarti* (Smith) McCull. (All figures magnified about 500 times.)

diseases of corn, but it is possible for the grower to choose agronomically desirable and adapted strains that are also resistant to the particular diseases most destructive in his locality.

HYBRID CORN AND DISEASE RESISTANCE

With the rapid increase in the use of hybrid corn certain aspects regarding resistance to disease in this crop have been altered. In general, as hybrid corn has been developed, there has been constant selection toward resistance to the major diseases. In some instances, however, resistance may have been sacrificed for other desirable characters. It is therefore important that the corn grower know the reaction to disease of the inbred lines combined in any particular hybrid and the relative resistance of the hybrid itself. Fortunately, the tendency toward disease susceptibility in one inbred line may be recessive or covered up when combined with highly resistant lines in making up the hybrid. If, however, two or three of the four inbred lines that make up the hybrid all show susceptibility to a certain disease, the chances are increased that the hybrid will be very susceptible.

There is a question in the minds of some regarding the relative resistance to disease of hybrids as compared with open-pollinated corn. It should be realized that any open-pollinated variety is made up of a population of plants differing from one another in agronomic characters, disease reaction, and response to environmental conditions. In contrast to this situation any one hybrid is composed of plants that are very uniform in these characters. There is thus a strong tendency for the plants of any given hybrid to respond similarly to any disease; the plants will all tend toward resistance or all tend toward susceptibility, depending upon the inherent make-up of the hybrid.

Some hybrids have been shown to be adapted to an unusually wide range of environmental conditions; even more so than some of the good open-pollinated varieties. Other hybrids are rather limited in their adaptation and produce their maximum only under relatively specific growing conditions. It is therefore important to choose hybrids that have proved their adaptability to the area in which they are to be grown. Hybrids or varieties that are grown in a region to which they are unadapted will frequently be injured by diseases for which no selection for resistance has been made.

In the production of hybrid corn the responsibility of selection for disease resistance rests upon relatively few individuals, that is, the seed-corn breeders, whereas in the case of open-pollinated corn the grower makes his own selections for disease resistance, as well as other desirable characters, at each harvest season. Although the hybrid-seed-corn producer ordinarily exercises little control in modifying the inherent resistance of the crop, he may play an important role in the production of healthy seed by culling out diseased and immature ears, by properly drying and grading his product, by handling it carefully during processing to prevent seed injury, and finally by treating it with some recommended fungicide. Such precautionary steps as these will tend to eliminate seed that is predisposed to attack by seedling-disease fungi.

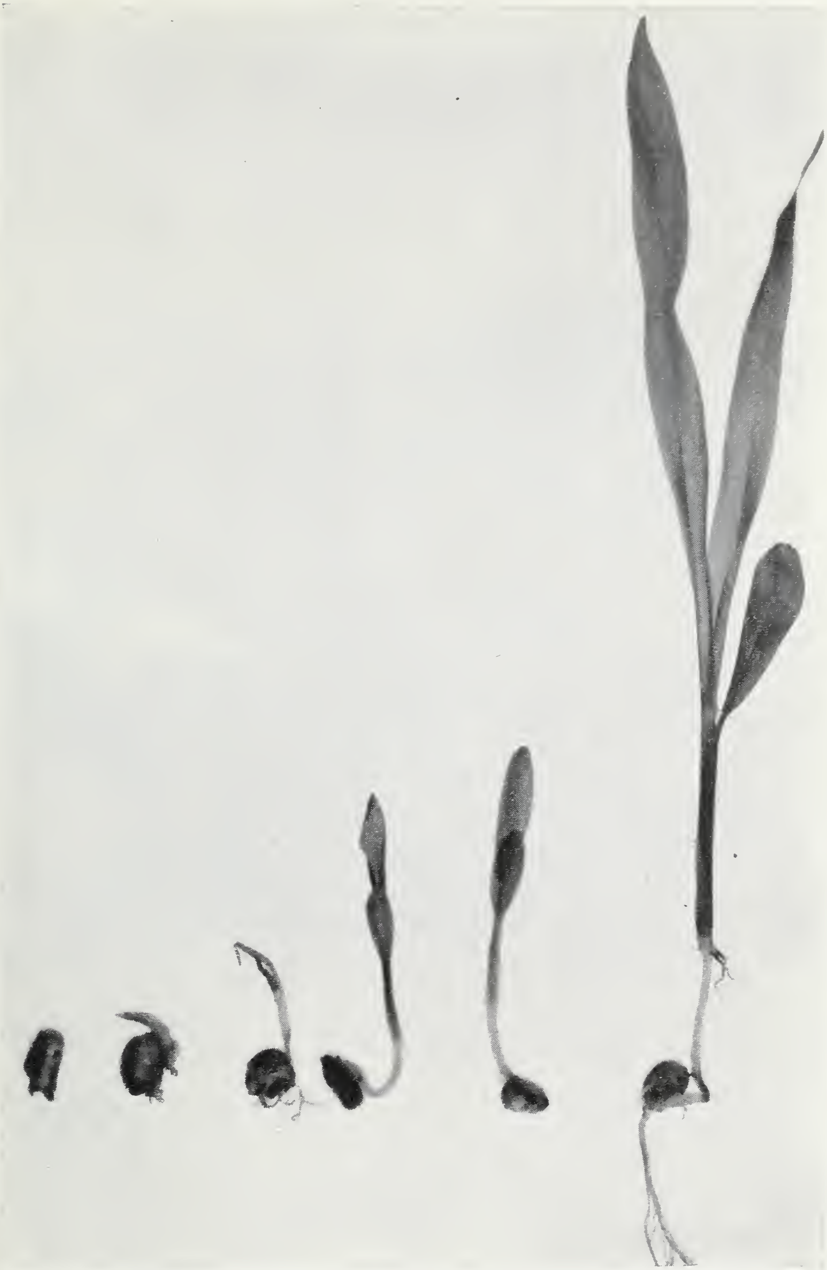

FIGURE 2.—Seedlings showing various degrees of seedling blight, from the killing of the embryo before germination (at left) to slight infection of the mesocotyl (at right).

SEEDLING DISEASES

The extent of the seedling diseases fluctuates from year to year, depending on the climatic conditions prevailing after the seed is planted, on the degree of infection in the seed itself, and on the resistance of the hybrid or variety. Diseases of seedlings result in poor stands through actual killing of the plants before emergence and in reduced vigor of plants surviving infection (fig. 2).

When seed is planted in cold, wet soil, or when cold, wet weather follows planting, infection may take place before and during germination. Corn seed may have slight infections not apparent to the naked eye. When such seed is planted the disease develops and may destroy or seriously injure the young plant.

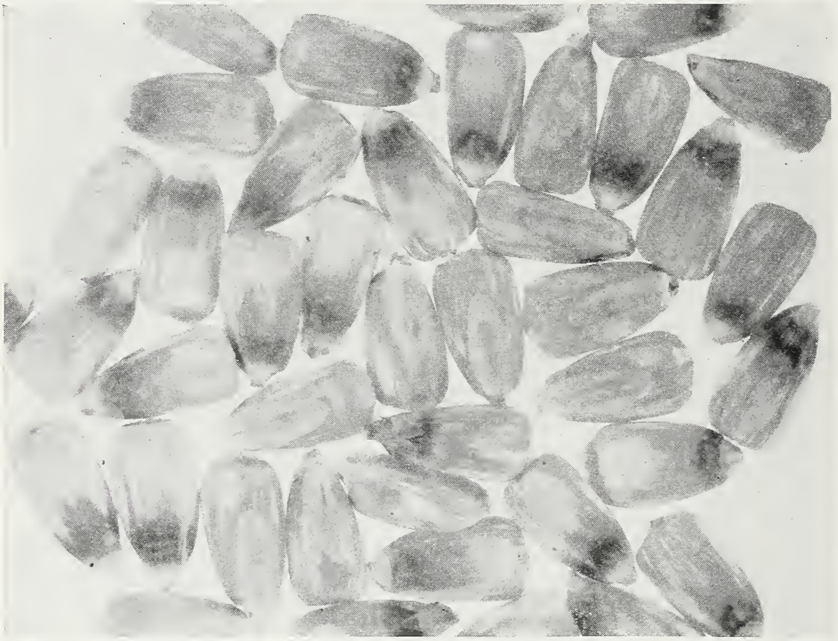

FIGURE 3.—Streaked kernels. Such streaking indicates fungus infection, and kernels exhibiting this condition should not be used for seed.

A number of fungi are able to cause seedling blight. In addition to the ear rot fungi, which may infect and kill the seedlings, such fungi as species of *Aspergillus*, *Penicillium*, and *Pythium* are known to attack seedlings. Most of these seedling-disease parasites are carried on or within the seed. Under some circumstances, however, infection arises from such soil-inhabiting fungi as *Pythium*.

Seedling diseases may be controlled to a considerable extent by employing preventive measures. (1) Use only well-matured seed; immature seed produces seedlings of reduced vigor that are subject to attack by fungus parasites. (2) Use certified seed. For certification most States require a germination test, which not only indicates how well the seed germinates but also furnishes a means of determining the extent of infection in the seed. Seed lots showing appreciable infection are not certified. (3) Treat seed corn with some recommended fungicidal dust; this will protect the seedling from infection to a considerable extent. (4) Do not plant seed until all danger of cold, wet weather is past. (5) Use hybrids or varieties that show resistance to seedling diseases. (6) Avoid seed that is discolored or has an abundance of broken caps. Broken seed coats permit the entrance of seedling disease fungi. Kernels that show streaking on the seed coat (fig. 3) indicate fungus infection.

ROOT DISEASES

Pythium Root Rot

The prevalence of pythium root rot fluctuates from year to year. It is most abundant on young plants that have been subjected to extended periods of cold, wet weather. Although the disease is not of major importance over the Corn Belt as a whole, instances have been reported where serious losses occurred.

The disease may manifest itself by rotting the embryo and thus preventing germination, or by rotting secondary rootlets and causing a stunting of the seedling. Seedlings that survive attack are reduced in vigor and develop into poor, unthrifty plants. Symptoms on somewhat older plants include weak root systems, stunting, lodging, and premature death. The fungus attacks the root hairs and finer roots of plants. These roots, in the early stages of the disease, appear water-soaked but are only slightly discolored. The infected portions of the root are soon overrun by saprophytic bacteria and fungi that complete the destruction of the tissues. In advanced stages of the disease much of the root system is destroyed, the roots that remain are flaccid and discolored, and such plants can be pulled up easily.

The disease is caused by a fungus known as *Pythium arrhenomanes* Drechs., which lives in the soil; no instances of its being carried on seed are known. This same fungus has been found to cause root rot of sugarcane, wheat, oats, sorghum, and a number of grasses.

Where the disease is severe, one of the most practical means of control is rotation with such crops as legumes, which are immune from the fungus. Differences in resistance exist between various inbred lines of corn. Further information on this point is needed.[2]

Other Root Rots

At different times other fungi, primarily *Gibberella zeae* (Schw.) Petch and *G. fujikuroi* (Saw.) Wr. (*Fusarium moniliforme* Sheld.), have been isolated from diseased corn roots. The general opinion, however, is that these fungi are secondary invaders and are of little importance in starting infection. Such secondary organisms may accelerate the complete rotting of the roots. The fungus *Diplodia zeae* (Schw.) Lév. may at times cause a rotting of the root system, but this fungus is primarily associated with infection of the crown and stalk and other parts of the corn plant.

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[2] In this circular, where resistant hybrids or varieties are recommended for the control of a disease, the State agricultural experiment station should be consulted for information relative to the resistance of specific hybrids to any given disease.

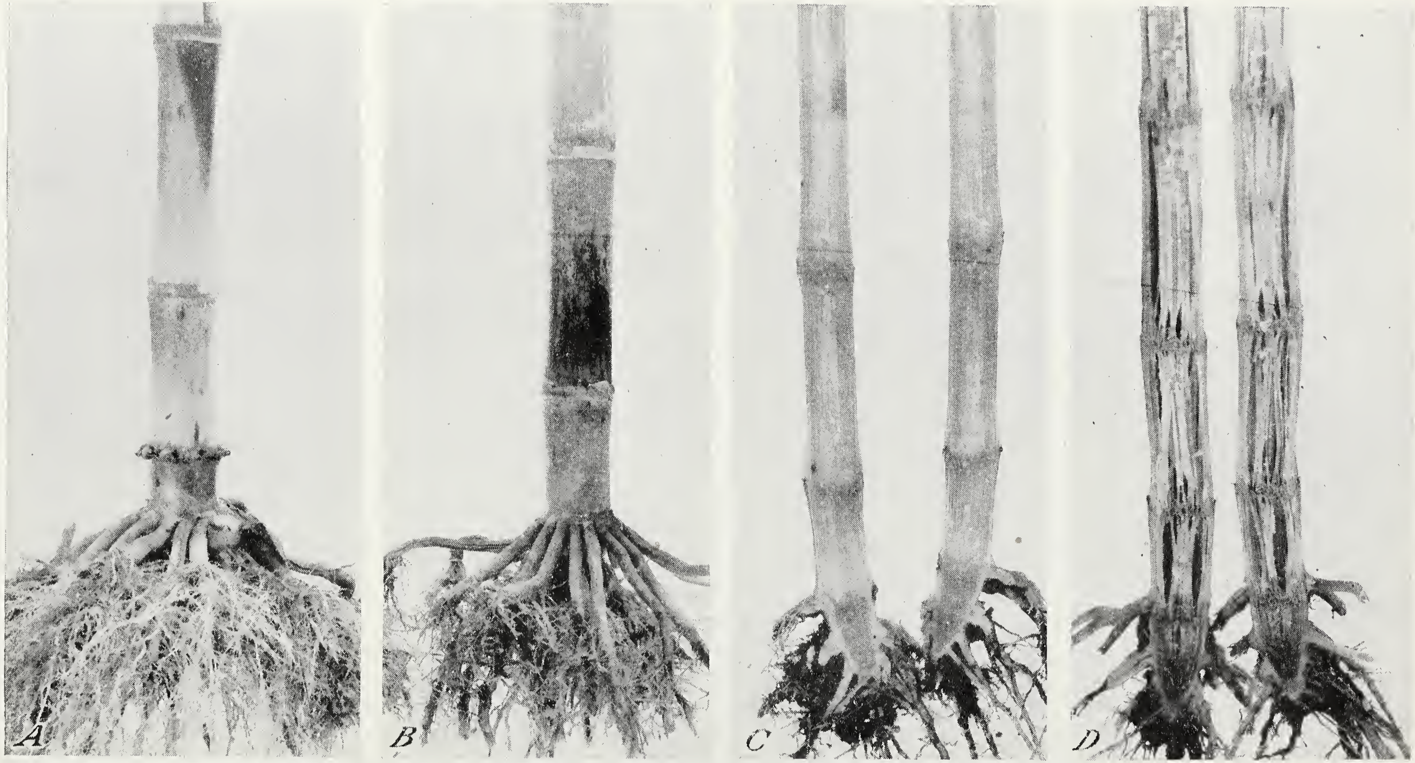

FIGURE 4.—Lower portions of cornstalks. *A*, Exterior view of a healthy stalk. *B*, Exterior view of a stalk affected with diplodia stalk rot. *C*, Healthy stalk split open to show condition of the pith. *D*, Diseased stalk showing shredded and discolored condition of the pith.

STALK DISEASES

DIPLODIA STALK ROT

Diplodia stalk rot is responsible for most of the stalk breaking observed in cornfields before and during the harvest season. This disease is present to a greater or lesser extent each year throughout most of the Corn Belt and may be found wherever corn is grown. The development of stalk rot appears to depend to a great extent on weather conditions, particularly on abundant rainfall during the latter part of the growing season. Stalks of plants injured by cold, leaf diseases, or chinch bugs are especially susceptible to attack by this disease. Plants affected early may die prematurely and produce light chaffy ears. Stalk breaking not only makes harvesting difficult but

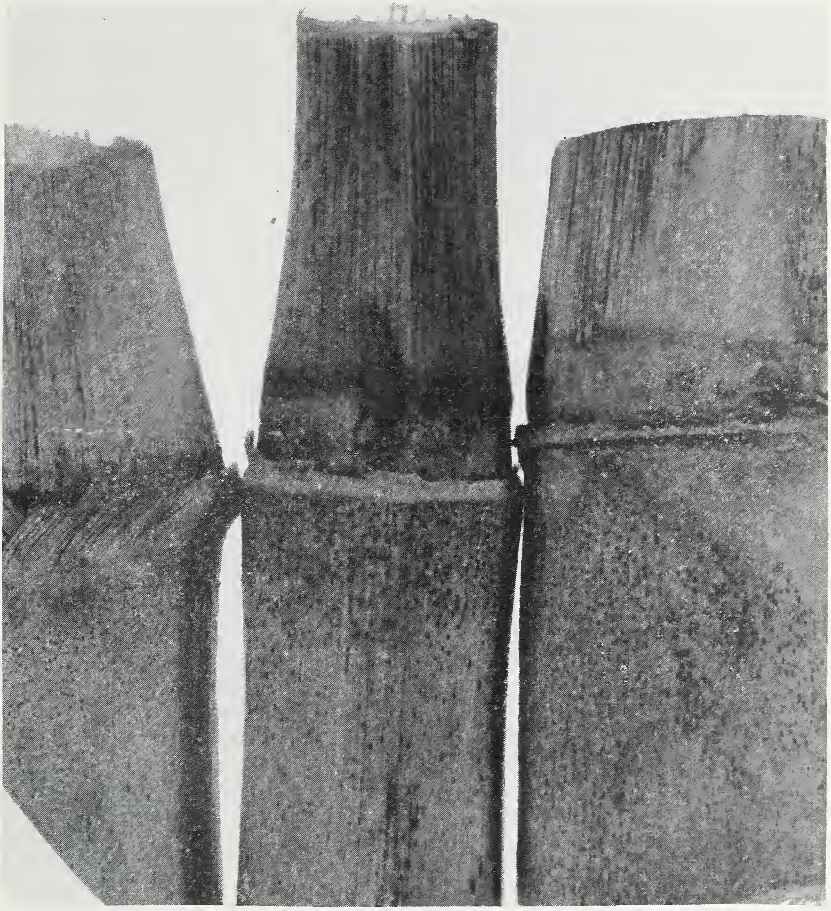

FIGURE 5.—The black flecks scattered over these dead stalks are the fruiting bodies, or pycnidia, of the fungus *Diplodia zeae*. Spores are discharged from these vessellike structures during the growing season and serve as a source of infection.

may bring the ears in contact with the soil, greatly increasing their chances of rotting.

Diplodia stalk rot tends to accompany the approach of maturity of the corn plant. Only rarely are stalks attacked before the ears have reached the dough stage. The first symptoms on the stalk are light-brown discolorations and softening of the lower internodes. As the disease progresses the browning of the exterior of the stalk intensifies and spreads to other internodes, and the pith becomes shredded (fig. 4, *B* and *D*). Some shrinkage of the stalk also occurs. Where conditions are ideal for rapid development of the disease, the entire plant will suddenly present a wilted and dead-green appearance very similar to that following early frost damage. Such plants die rapidly, and the leaves become dry and soon shatter.

The disease is caused by the fungus *Diplodia zeae* (Schw.) Lév., which gains entrance into the stalk from the crown of the plant or through the nodes. Plants may be attacked also as seedlings, and, if these survive, the infection may remain inactive below the soil line in the crown of the plant. With the approach of maturity the infection may spread from the crown to the stalk tissues. Infection may take place also through the nodes by spores of the fungus that lodge between the stalk and the leaf sheath. These spores germinate and penetrate into the nodal tissues.

Diplodia zeae, the fungus causing the disease, lives over winter on cornstalks left in the field and can be seen in the fall or the following spring and summer as slightly raised black specks, especially around the nodes of the dead stalks (fig. 5). These are minute vessellike bodies containing large numbers of spores (see fig. 1, *E*), and during moist weather the spores ooze from these bodies, or pycnidia as they are called, and when dry are spread by wind currents.

The best means of controlling this disease is through the use of resistant hybrids or varieties. There are very marked differences in resistance to this disease among the various hybrids, and where stalk rot is an important factor hybrids or varieties of high resistance should be selected. When early maturing hybrids, or varieties, are grown in areas having a long growing season, they frequently succumb to this disease. It is therefore important to choose corn that is well adapted to the area where it is to be grown, having the ability to make full use of the entire growing season. Well-balanced fertility of the soil also is a factor that tends to reduce losses from this disease.

Bacterial Stalk Rot

Bacterial stalk rot is seldom of any great economic importance and is confined for the most part to the southern areas of the Corn Belt. It appears to be more abundant when hot, damp weather prevails and in fields where flooding has occurred.

Young as well as old plants may be attacked. The principal symptom is a brown discolored area near the base of the stalk, which rapidly develops to a soft, rotten condition. The disease does not spread rapidly up and down the stalk, and rotting appears rather to pass transversely through the stalk. In advanced stages of the disease the stalk is so weakened that it breaks over (fig. 6).

The disease is caused by a bacterium, *Phytomonas dissolvens* Rosen, that gains entrance through mechanical wounds, insect injury, or

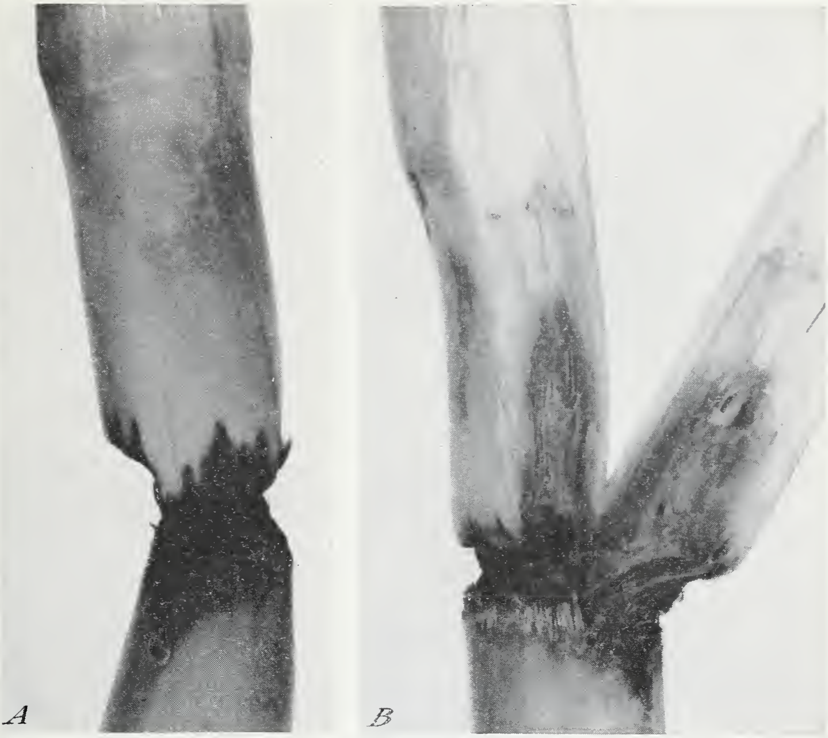

FIGURE 6.—Bacterial stalk rot: *A*, External view; *B*, internal view.

stomata. It is believed that the bacterium lives over from one year to the next on infected corn stubble. No definite control measures are known, but rotation would probably minimize losses, as corn is the only plant known to be susceptible to the disease.

OTHER STALK DISEASES

Gibberella stalk rot occurs in the northern areas of the Corn Belt. The prevalence of the disease fluctuates a great deal from year to year and only occasionally does it occur abundantly. Rotting usually is confined to the crown or the lower internodes. The interior of the stalk becomes more or less shredded and red or pink. Like diplodia stalk rot, this stalk rot becomes evident as the plant approaches maturity.

The disease is caused by the fungus *Gibberella zeae* (Schw.) Petch, which lives from one season to the next on old stalks and stubble in the field. The spore-bearing bodies, or perithecia, of the fungus occur on the surface of the old stalks from the previous year as small bluish-black, globular structures and are especially abundant about the nodes (fig. 7). When the weather is mild or warm and there is sufficient moisture, spores (fig. 1, *B*, *b*), which are produced in minute sacks (fig. 1, *B*, *a*) within the spore-bearing bodies, are discharged and infect plants that are in a susceptible condition.

Control of this disease may be obtained through the use of hybrids and varieties that are resistant—corn strains showing resistance to diplodia stalk rot appear to be resistant also to gibberella stalk rot. Clean plowing of corn stubble fields, in order to bury the fungus on the old stalks, together with crop rotation, tends to reduce losses from this stalk rot.

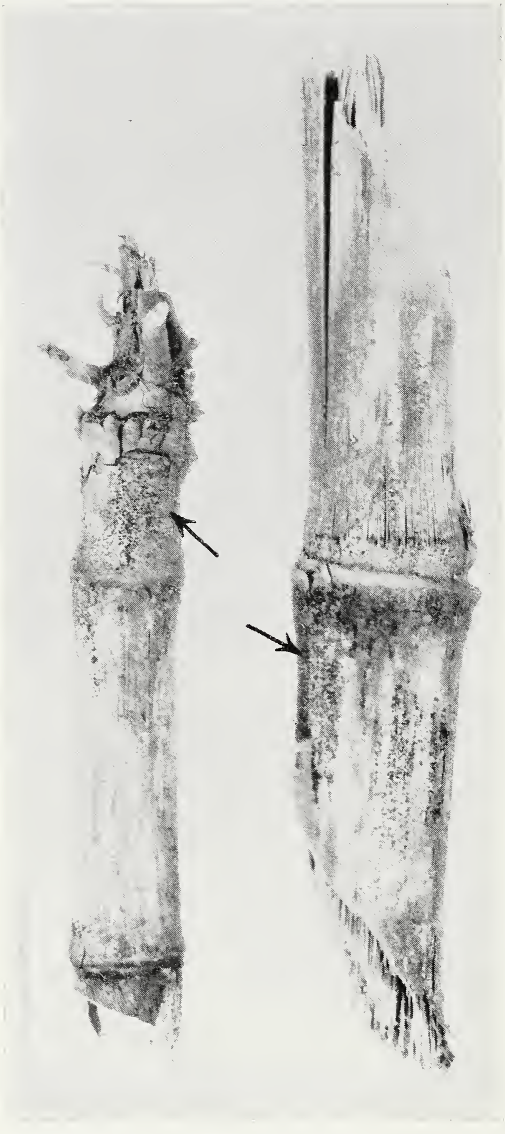

Figure 7.—The small black globular structures on the surface of old cornstalks are the spore bodies (perithecia) of the fungus *Gibberella zeae.* Spores from these bodies infect ears and stalks of corn.

Charcoal rot is a disease of the cornstalk which occasionally causes some damage, particularly in the southern and western parts of the Corn Belt. The symptoms are black streaks on the exterior of the lower portions of the stalk. When such stalks are split, the pith will be found to be shredded, and the fungus, which causes the blackening, is found scattered in the tissues. The disease usually occurs when plants are mature or are unthrifty because of some type of injury such as drought, cold, or low fertility. Charcoal rot is caused by the fungus *Sclerotium bataticola* Taub., which may attack a wide range of unrelated plants. Sorghum stalks are more often affected than corn by this disease.

Occasionally other fungi, such as *Basisporium gallarum* Moll. and *Gibberella fujikuroi* (Saw.) Wr. (*Fusarium moniliforme* Sheld.), have been identified with stalk rot, but these are not particularly important. In most instances the indications are that the fungi followed infections caused by *Diplodia zeae* or attacked the plant when the latter was in a very low state of vigor.

LEAF DISEASES

There are a number of leaf diseases of corn that occur more or less throughout the United States. In general, they are not as important as smut, the ear rots, or stalk rots, but under some circumstances considerable damage to the leaves occurs. Where appreciable amounts of leaf tissue are killed the plant as a whole is reduced in vigor, yields poorly, and is more subject to attacks by other diseases, particularly diplodia stalk rot.

The condition frequently referred to as "leaf blight" may often be caused by a complex of two or more diseases, such as bacterial wilt and a helminthosporium leaf disease. When two or more diseases occur together, it is often difficult to determine which is responsible for the greatest damage.

Bacterial Wilt

Bacterial wilt, also known as "Stewart's disease," is primarily a disease of sweet corn, popcorn, and flint corn and usually is of minor importance on dent corn. In some years rather heavy epidemics of so-called "late infection" are found on field corn, and under such conditions appreciable losses result. It is only rarely that dent corn is so badly infected in the early stages of growth that wilting, stunting, and death occur.

Early infection on dent corn exhibits symptoms very similar to those on affected sweet corn. Conspicuous light-green or yellow stripes occur longitudinally through the leaves. These infected tissues die and become brown and dry. Such infected plants may die, or if they recover they remain stunted and unthrifty.

Late infection, or bacterial leaf blight, is the more important manifestation of this disease on dent corn. The symptoms are characterized by long irregular dead streaks running along the veins of the leaves (fig. 8). These symptoms are more abundant on the lower leaves, and the origin of a lesion centers about a point where a corn flea beetle has fed on the leaf. The feeding marks are very distinct and have the appearance of short linear scratches, which, when the leaf is held to the light, permit the light to pass through. If pieces of the leaf veins bordering the lesions are examined under a microscope, abundant bacterial exudate may be seen oozing from their ends. Lesions are scattered over the leaves, and in severe cases one-third to one-half of the leaf area is killed. In severe cases where there is considerable reduction in leaf area the ear may become chaffy, and the stalk appears to become more susceptible to diplodia stalk rot.

Symptoms of bacterial wilt on the leaves are often mistaken for symptoms of potash or nitrogen deficiencies or certain injuries from drought and heat. Potash-deficiency symptoms on the leaves appear as dead, dry areas only along the margin (fig. 9, *A*). Nitrogen deficiency shows characteristic yellowing and drying of the leaf tissue, beginning at the tip and following along the midrib (fig. 9, *B*). Drought and heat injury may manifest itself as "firing" of the topmost leaf or two under very severe conditions, or the lower leaves may dry up. Death of the tissues in these instances is usually general, and no particular pattern is formed on the leaf. Certain hybrids show a peculiar symptom due to drought, which is some-

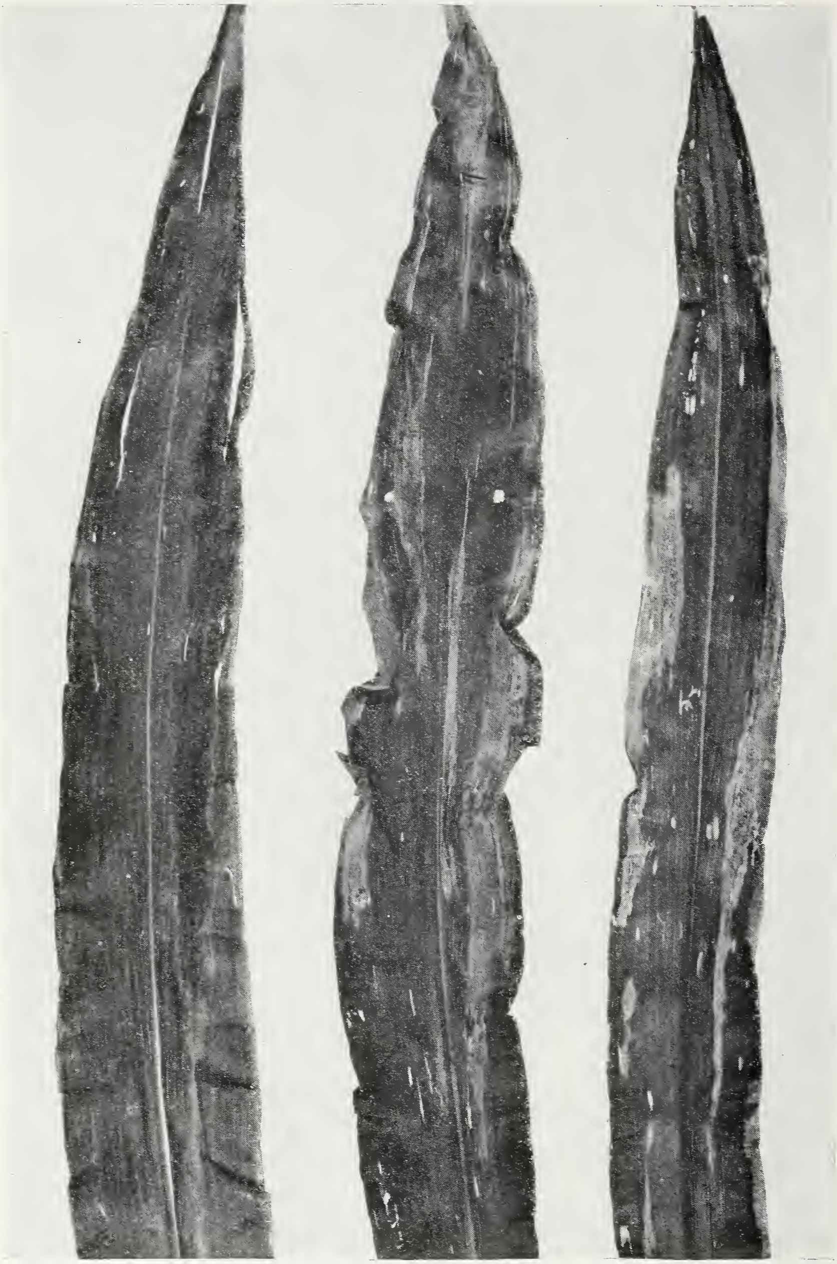

FIGURE 8.—Late infection of bacterial wilt on corn leaves. Note that the long irregular dead streaks are distinctly different from those shown in figures 9 and 10.

times referred to as "dying between the veins" or "intervascular dying" (fig. 10). This condition is manifested by streaks of dead tissue extending parallel to the veins and is distinguished from the leaf symptoms produced by bacterial wilt by the regularity in occurrence of the streaks over the leaf blade and the rather uniform width of the dead areas.

Bacterial wilt is caused by a bacterial organism (see fig. 1, *J*) known as *Aplanobacter stewarti* (Smith) McCull. This organism may live in a relatively dry condition in corn tissue for some time without injury. Most of the initial infection on dent corn arises from bacteria that have lived over the winter in the bodies of hibernating flea beetles. These insects harbor the bacteria over winter and carry them to the corn plants during the following growing season.

Where this disease causes appreciable damage, adapted hybrids known to be resistant should be grown.

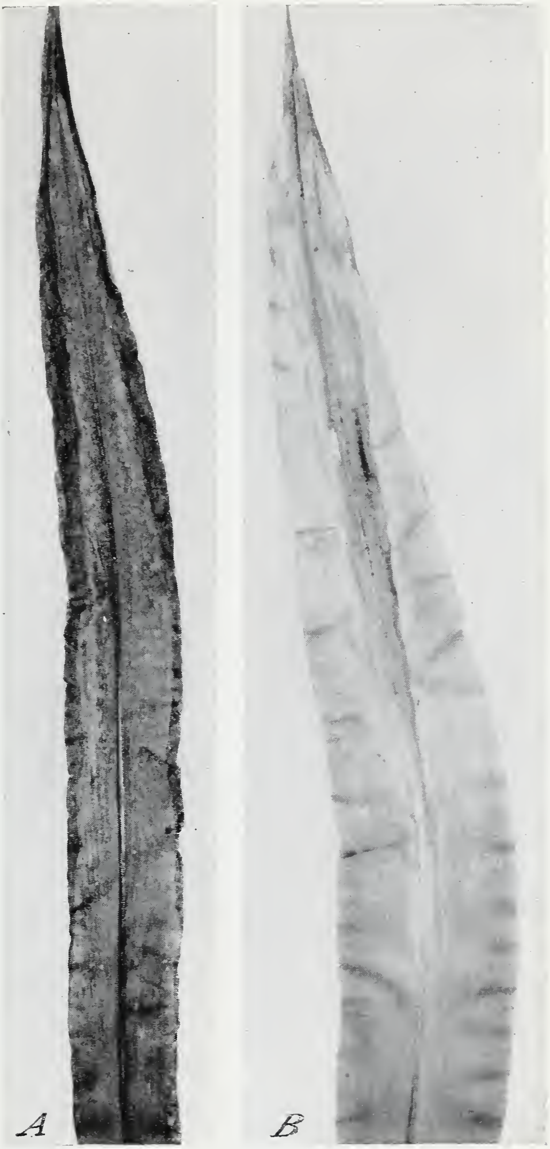

FIGURE 9.—*A*, Potash-deficiency symptoms; leaf shows firing along margins. *B*, Nitrogen-deficiency symptoms; leaf shows firing progressing from tip down along the midrib.

HELMINTHOSPORIUM DISEASES

There are four helminthosporium leaf spots of corn, caused by different species or races. These diseases, sometimes referred to as leaf blight or leaf spot, usually have been of minor importance in the Corn Belt. Within recent years, however, these leaf diseases have been known to cause considerable damage on susceptible inbred lines and hybrids. During wet seasons and especially on low ground, such as river bottoms where dew remains on the plants for extended periods, these diseases become aggressive. In the South two of these diseases are important also on native open-pollinated varieties.

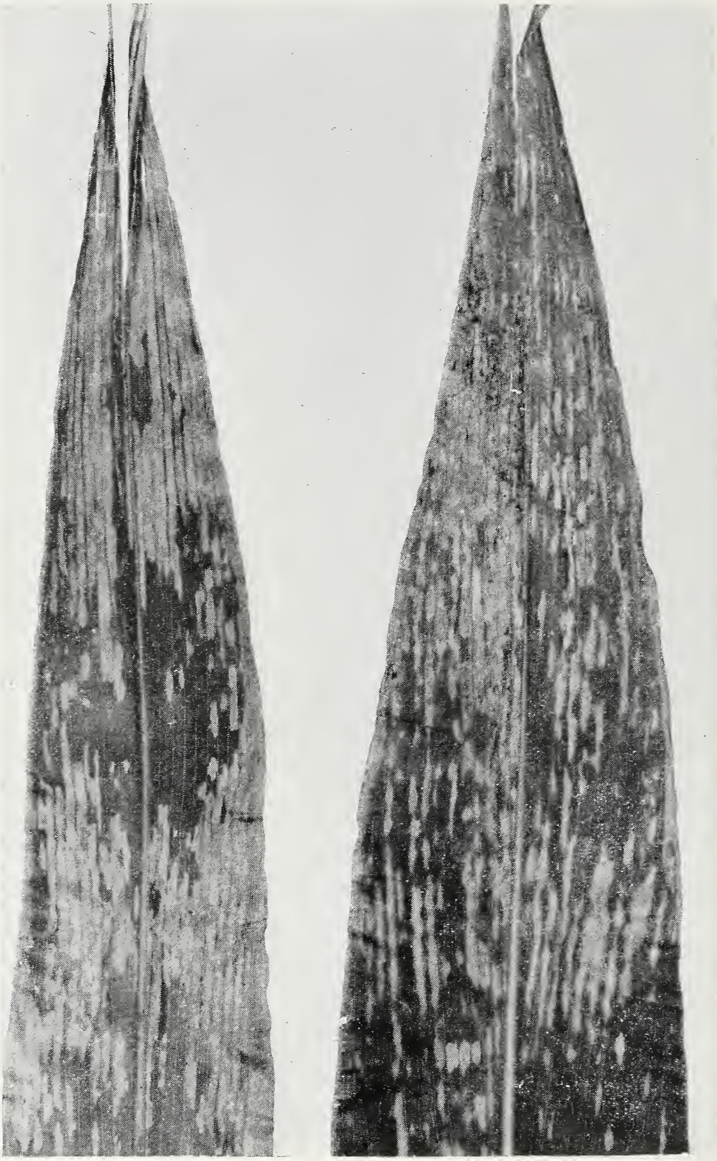

FIGURE 10.—"Dying between the veins." This is a peculiar symptom shown by some hybrids under drought conditions.

One of these diseases, caused by *Helminthosporium turcicum* Pass., is very widespread in its occurrence. The leaf lesions appear as long elliptical areas greenish brown in color and show concentric zones of different shades of brown (fig. 11, *A*). Leaves heavily infected appear as if fired, and little green area remains.

Appreciable damage by *Helminthosporium turcicum* has occurred in some seasons in Indiana, Ohio, and some of the Eastern States.

The leaf disease caused by *Cochliobolous heterostrophus* Drechs. (*Helminthosporium maydis* Nisikado and Miyake) is confined to the Southern States, where it is often known as corn leaf spot. The lesions on the leaves are distinct from those caused by *H. turcicum*, being smaller, more numerous, and of a different pattern and color. The spots are somewhat longer than wide, are buff with a reddish-brown margin, and have a definite zonate or targetlike pattern. Severe infection may sufficiently reduce the leaf area to cause lowering of yields.

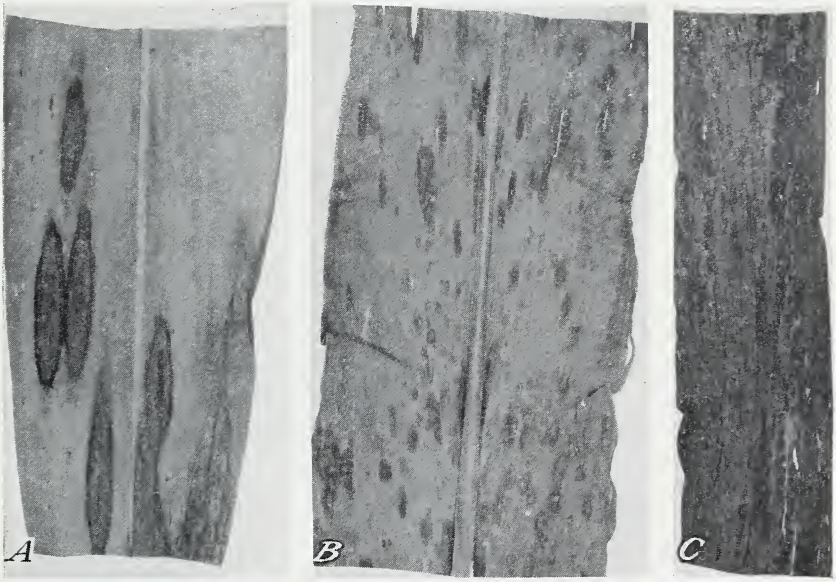

FIGURE 11.—Symptoms on corn leaves caused by *A*, *Helminthosporium turcicum;* *B*, a race of *Helminthosporium* sp. found in the Corn Belt; *C*, a second race of *Helminthosporium* sp. found in the Corn Belt.

Although no corn is known to be immune from this disease, certain inbred lines are relatively resistant. From these inbred lines resistant hybrids may be developed to control the disease.

A third helminthosporium disease of corn, thus far observed only on inbred lines, has been found in recent years in the Corn Belt. This species, not completely identified, was originally believed to be *Helminthosporium maydis*, but recent evidence has shown it to be distinct. The fungus appears to be composed of two races, alike in form and structure but differing in the symptoms they produce and in the inbred lines they attack.

The symptoms produced by race I (fig. 11, *B*) are similar to those caused by *Cochliobolus heterostrophus*. This disease, however, is thus far known to be confined only to the inbred lines Pr, K61, and K44. When any of these inbreds is crossed with a resistant line the hybrid is completely resistant.

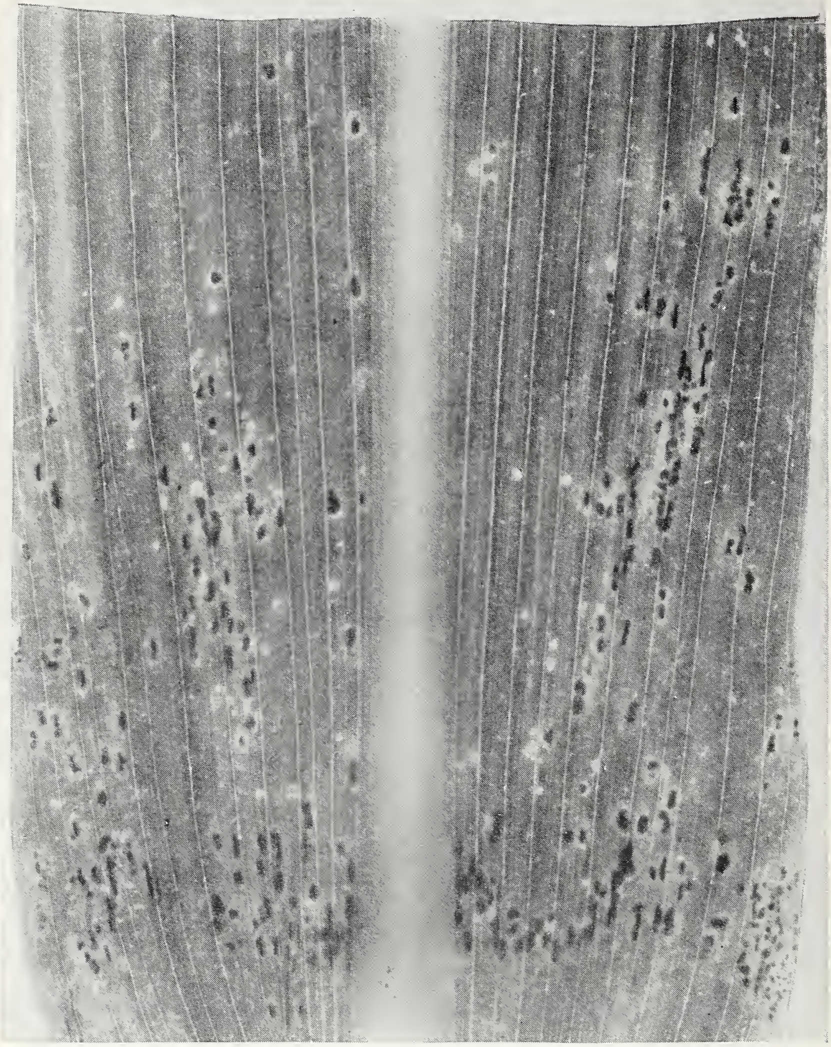

FIGURE 12.—Rust on corn leaf.

The symptoms produced by race II (fig. 11, *C*) are only occasionally found on leaves and appear as narrow, irregular, chocolate-brown spots. Both races of this species of *Helminthosporium* attack the ears, producing a black moldy growth over the kernels, which gives the ear the appearance of being charred.

All helminthosporium diseases of corn are spread by spores that are carried by wind currents. When wet humid conditions prevail, large numbers of these spores are able to germinate and cause further infections. The fungi causing these diseases survive from one season to another on old infected leaves in the field.

The most effective means of control is through the incorporation of the resistance of certain inbred lines into susceptible, but otherwise desirable, inbred lines.

RUST

Corn rust occurs more or less wherever corn is grown. In some years considerable quantities may be seen, and in other years it is practically absent. It seldom is known to cause any noticeable damage to the crop. Occasionally, however, it is sufficiently abundant to be of importance.

Rust occurs on the leaves as small reddish-brown pustules that break through the epidermis (fig. 12). When examined closely, or rubbed, these pustules are found to contain a brown powdery material composed of masses of summer spores of the rust fungus. Toward the end of the growing season the pustules become dark brown or black. This is owing to the replacement of the summer spores by the black or so-called winter spores. These summer and winter spores are illustrated in figure 1, *G*, *a* and *b*, respectively.

Corn rust is caused by the fungus *Puccinia sorghi* Schw. The rusty-brown summer spores may overwinter in the Corn Belt areas and infect corn directly the following season. The black winter spores overwinter in the corn leaves and germinate in the spring to form small transparent spores, which may infect an entirely different kind of plant, the wood sorrel (*Oxalis* spp.). On this plant, spores of still another kind are produced which, in turn, may infect the corn leaves, where the rusty-brown summer spores and later the black winter spores are again produced.

Since this disease is of such minor importance, little effort has been directed toward breeding for resistance to it. There are, however, wide differences in resistance among strains.

PURPLE SHEATH SPOT

Purple sheath spot occurs in almost every cornfield in the latter part of the season, but like rust its damage is negligible.

Symptoms appear as purple or brownish irregular blotches on the leaf sheaths (fig. 13). The outer epidermis of the sheath remains intact, but the inside becomes cracked and partly rotted.

Studies on the disease have indicated that a number of fungi and bacteria may cause the condition. Ordinarily these organisms are saprophytic and become active parasites only under favorable conditions. Such fungi and bacteria lodge between the sheath and stalk, where with sufficient moisture they germinate and live on dead material such as old pollen. These organisms, having attained some development, may penetrate the tissues of the sheath and cause spotting. Inasmuch as the disease is not troublesome no control measures have been worked out, although marked differences among strains in susceptibility to such spotting are evident.

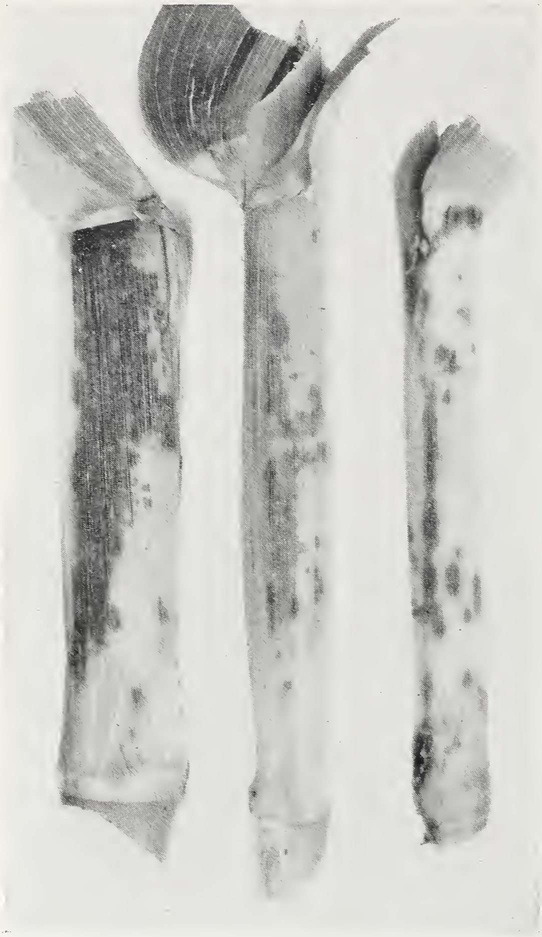

FIGURE 13.—Purple sheath spot.

BROWN SPOT

Brown spot, or physoderma disease, occurs only rarely in the Corn Belt and then only in the southern areas. It is found in the Gulf and South Atlantic States where high temperatures and high humidity and rainfall prevail. In certain instances it has caused considerable damage in some of these areas.

Golden to brown circular pustules appear on the leaf blades and sheaths (fig. 14). In some cases severe infections on the stalk have been responsible for stalk breaking. This disease may be mistaken for rust. The rust pustules, however, are rough and powdery and break the epidermis, whereas brown spot lesions are smooth and the pustules usually do not break the epidermis. The disease is caused by the fungus *Physoderma zeae-maydis* Shaw. The spots contain numerous spores of the fungus, and these spores serve to distribute and propagate the parasite. Under conditions of high temperature and free moisture, these spores germinate to liberate minute, motile spores or "swarm" spores. These secondary spores produce germ tubes that infect the host plant.

No definite control measures are known, although differences in resistance exist.

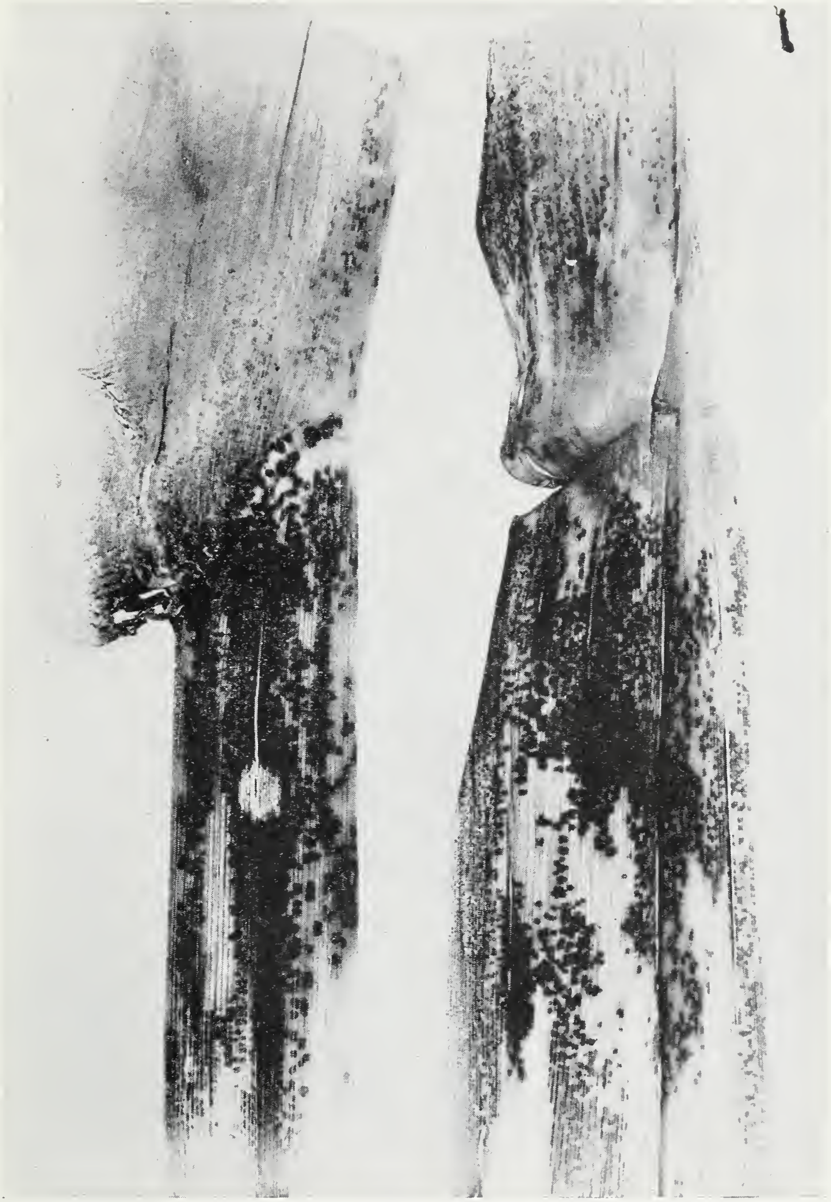

FIGURE 14.—Brown spot on leaf blades and sheath of corn leaves.

EAR ROTS

Diplodia Ear Rot

Of the several diseases known to attack the ear, diplodia ear rot, also known as dry rot or white rot, appears to be most abundant in the principal corn-growing areas of the United States. Under conditions favorable for its development it may cause serious losses. Where the percentage of infection is high, yield is reduced and the grade of corn is lowered. In addition to these losses, infected kernels are low in nutritional value and are practically worthless as seed.

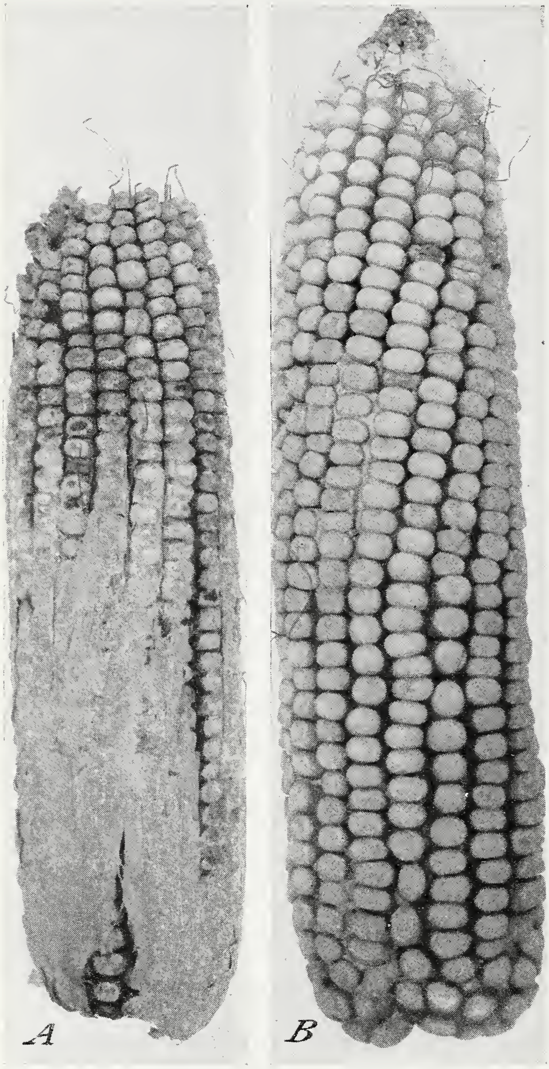

FIGURE 15.—Diplodia ear rot: *A*, Ear infected early, having a grayish-brown, mummified appearance. Black specks near base of husk are the fungus bodies (pycnidia). *B*, Ear showing slight infection by the fungus *Diplodia zeae*. Note the whitish mold between kernels.

The disease is to be found in nearly all of the principal corn-growing areas of the world and is especially abundant in those parts where there is ample moisture during the time of maturation. In the eastern half of the United States diplodia ear rot is present in varying degrees of severity every year. Toward the western edge of the Corn Belt and in the more northern areas it is frequently of little importance or is absent.

Diplodia ear rot usually does not develop until after the kernels have reached the soft-dough stage, although infection may take place at a much earlier time. The first symptoms of the disease in the field are the appearance of bleached husks and drooping of the ear. These symptoms are rather conspicuous in contrast to the healthy green upright ears. Infection most frequently takes place through the butt of the ear, the disease having progressed up from the shank. What is often known as shank rot is an early stage in the development of diplodia ear rot. In addition to infection through the shank, rotting may begin at the tip of the ear. Where infection takes place early and progresses rapidly (fig. 15, *A*), the ear may be completely rotted and mummified. On such badly diseased ears all the kernels are infected. Often such kernels assume a grayish-brown cast and small, black fungus bodies (pycnidia) usually occur on them and also on the husks and in the cob. Ears in this condition are dried out (hence the common name "dry rot") and light in weight, and the husks are "cemented" together by the growth of the fungus between them. In some instances where infection occurs late in the development of the ear the kernels may seem normal in all respects, and the ear may not be suspected of being diseased (fig. 15, *B*). When such ears are broken or the kernels are removed from the cob, discoloration and fungus growth frequently may be seen at the tip of the kernels. In contrast with other ear rots, diplodia ear rot is accompanied by a white or grayish development of the fungus, and, as the disease progresses over the ear, every kernel is involved.

Diplodia ear rot is caused chiefly by *Diplodia zeae*, the fungus that is responsible for diplodia stalk rot. Spores of the fungus (fig. 1, *E*), liberated during moist weather from the fungus bodies (pycnidia) on old stalks of the previous year's crop, are scattered by the wind. Spores lodge at the base of the shank between the husks or on the dry silk, where they germinate, when there is sufficient moisture, and penetrate the tissues.

In the southern areas of the United States another closely related fungus, *Diplodia macrospora* Earle, is responsible for considerable ear rot. The symptoms produced by it are essentially the same as those produced by *D. zeae*, and the life cycles of the two fungi also are similar.

Control of diplodia ear rots can best be obtained by avoiding hybrids and varieties known to be susceptible. Resistance to this disease is not complete, and all corn, even the most resistant, shows some infection if the fungi are present and conditions are favorable for their development. Successive cropping of land to corn tends to increase the abundance of the fungus, and therefore such practices should be avoided. Seed treatments have no controlling effect on the ear rot phase of the disease. Furthermore, plants affected with diplodia seedling blight or diplodia stalk rot will not necessarily produce ears with diplodia rot. Resistance to diplodia ear rot does not appear to be highly correlated with resistance to diplodia stalk rot. Because the fungus may be carried on or within the seed, lines suceptible to this ear rot may show considerable seedling blight unless precautionary measures are taken.

PINK EAR ROT

From an economic standpoint pink ear rot, which is frequently referred to as fusarium ear rot, usually does not approach the importance of diplodia ear rot in the central areas of the Corn Belt. One reason is that fusarium ear rot usually does not involve as much of the ear. Another reason is that, over a period of years, severe epidemics of the disease are less frequent than those of diplodia ear rot.

It has been observed that this disease is somewhat more abundant in dry seasons and in the western parts of the Corn Belt where dry weather usually prevails during the growing season. These observations have been correlated with studies to show that the causal fungus will develop on corn of a lower moisture content than will either *Diplodia zeae* or *Gibberella zeae.*

The symptoms usually are seen first after kernels are well dented (fig. 16). The rotting usually does not involve the entire ear as does diplodia ear rot but is more frequently found in spots scattered over the ear. Infected areas are characterized by being rather powdery in appearance and pinkish in color. Kernels that look normal may be infected with the fungus to some extent. In fact, it has been reported that a relatively high percentage of all corn kernels carries some of this fungus even though the kernels look normal. Such infections, however, are not of particular importance if the corn is properly stored. The disease very frequently enters the tip of the ear where kernels may be exposed, owing to poor covering by the husks, or may be injured in some way. This ear rot very commonly follows injuries to kernels by birds or earworms, and where such injuries are numerous this ear rot is abundant. "Popped" or cracked seed coats and so-called "silk-cut" (fig. 17) offer means by which the fungus is able to gain entrance to the kernels. Starchy, rough-kerneled ears appear to be somewhat more susceptible to this disease than are the smooth, hard-kerneled ears.

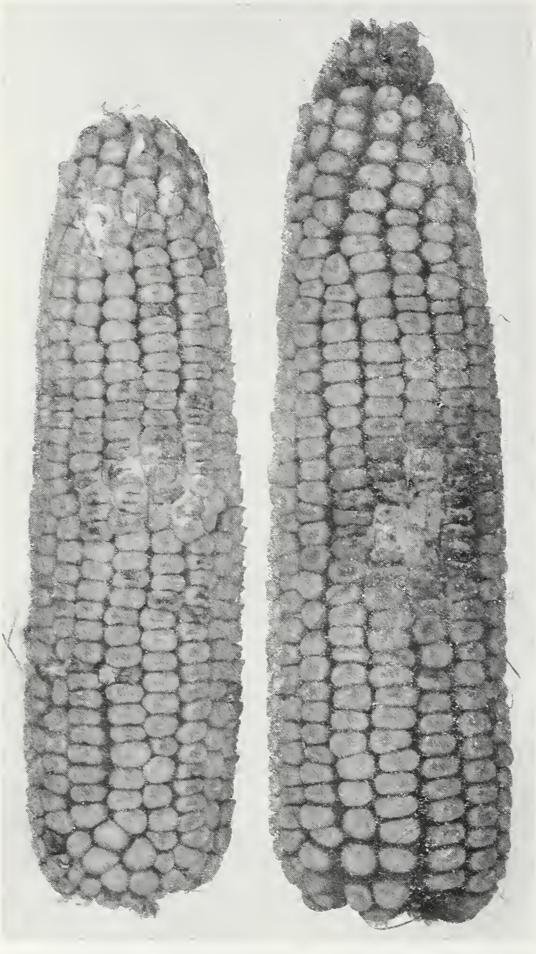

FIGURE 16.—Pink ear rot, or fusarium ear rot. Note spotted infections over the ears.

The disease is caused by the fungus *Gibberella fujikuroi* (Saw.) Wr. (*Fusarium moniliforme* (Sheld.) and the related species *G. fujikuroi* (Saw.) Wr. var. *subglutinans* Edwards (*F. moniliforme* Sheld. var. *subglutinans* Wr. and Reinking). Two kinds of spores of *G. fujikuroi* are illustrated in figure 1, *D, a* and *b*. These fungi are only microscopically distinguishable, and the ear rots produced by them are practically identical. The former species, however, is the more common in the United States. Both fungi live on old plant refuse in the soil and are carried on and within the seed.

Fusarium ear rot can best be controlled by avoiding hybrids and varieties known to be highly susceptible. In addition, strains of corn that have a tendency to produce short husks or that are prone to develop kernels with the so-called "silk-cut" or that are "popped" should not be selected.

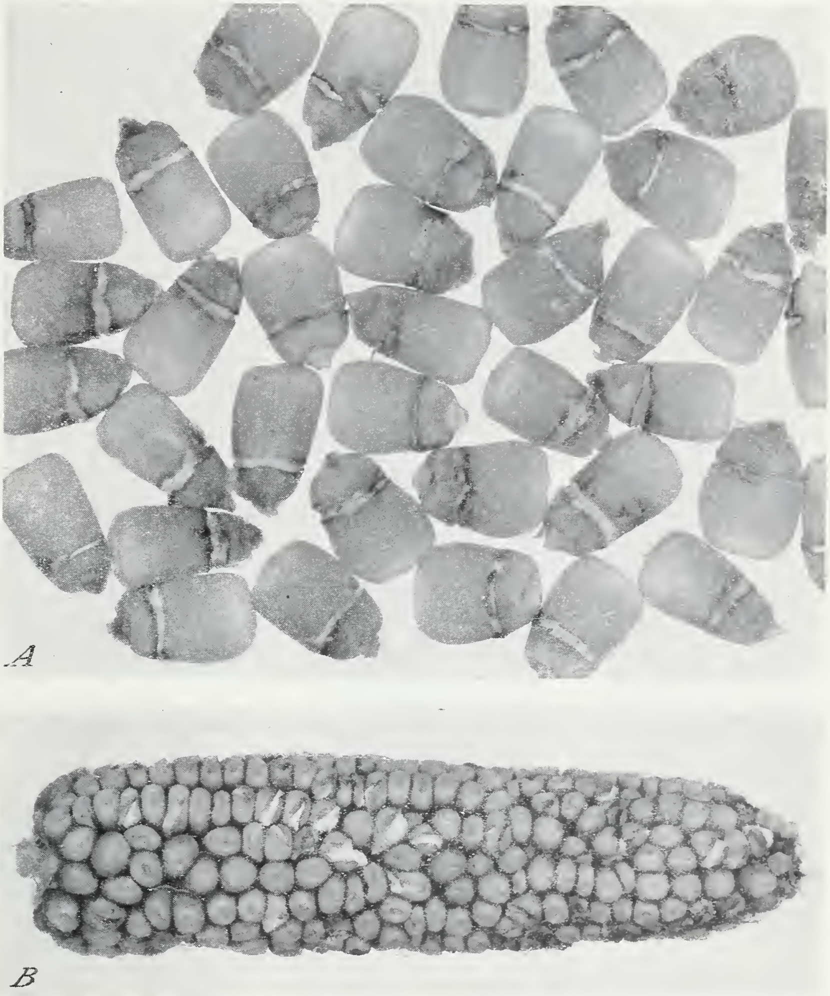

Figure 17.—*A*, "Silk-cut." Certain inbreds and hybrids show a tendency to break the seed coat in this manner. Such breaks usually become infected with *Gibberella fujikuroi* (*Fusarium moniliforme*). *B*, "Popped kernel." Another peculiarity shown by some lines. This condition offers avenues of infection for fungi, particularly *G. fujikuroi.*

Gibberella Ear Rot

Gibberella ear rot, sometimes called red ear rot, is of minor importance in the major corn-growing sections of the United States. In some areas, however, particularly the northern sections of the Corn Belt, this ear rot is troublesome at times.

This disease can be readily recognized by the characteristic reddish discoloration of the infected portions of the ear. Infection almost invariably begins at the tip of the ear and progresses toward the base; seldom, however, is the entire ear involved (fig. 18).

The disease is caused by the fungus *Gibberella zeae* (Schw.) Petch, the same fungus that causes gibberella stalk rot. The fungus lives in the soil and on old cornstalks and it is on these old stalks that fruiting bodies (perithecia) of the fungus occur (fig. 5). These are small bluish-black globular structures found on the surface of the stalks, especially near the nodes. When the spores (fig. 1, *B*, *b*) are mature they are exuded from the vessellike perithecia and lodge between the husks and on the silks of the ears, where they germinate, and the growth penetrates into the ear. Another type of spore (fig. 1, *C*) of the same fungus also may occur on the old stalks and infect the ears in the same way.

This disease, like the other ear rots, can be controlled to a considerable extent by using adapted hybrids and varieties that show a minimum of susceptibility. Clean plowing, in order to bury the old stalks on which the fungus overwinters and which serve as the initial source of infection the following season, tends to reduce the amount of disease. Rotation with crops that are not attacked by this fungus is advisable. Barley and wheat sown on disked corn ground may be damaged seriously by the scab disease, which is caused by the same fungus. Diseased ears should be discarded, since feeding them to certain farm animals, particularly swine, has resulted in toxic effects and sometimes death.

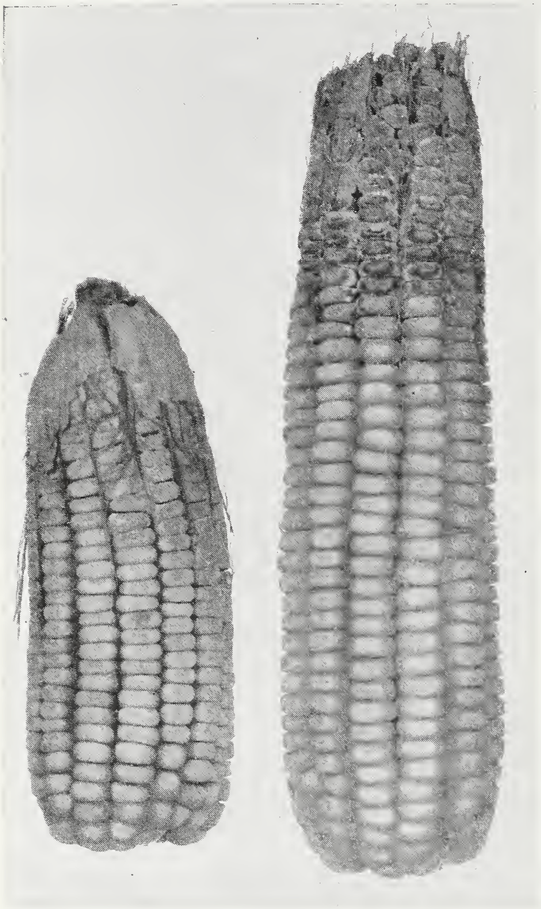

FIGURE 18.—Gibberella ear rot. Infection is usually confined to the upper half of the ear and shows a deep-pink or reddish discoloration. Husks are often "cemented" together and to the diseased part of the ear.

Nigrospora Ear Rot

Nigrospora ear rot, frequently known as basisporium cob rot, varies considerably in importance from year to year. It appears to be somewhat more prevalent in the northwestern sections of the Corn Belt than in other areas. Varying amounts of the disease, however, are found each year in most of the corn-growing areas of the United States. When the disease is severe, both the total yield and particularly the yield of marketable corn are reduced.

Badly infected ears are light in weight and break easily. The cobs of such ears have a shredded appearance; hence the name "cob rot" is frequently applied to this disease (fig. 19). Shredding is found also in the shanks of infected ears. The kernels often have a dull, bleached color, and the ear is chaffy. A very distinctive symptom of this disease is the presence of black spores (fig. 1, *H*) scattered over the butt end of the ear and on the tips of the kernels. Under conditions of sufficient moisture, the characteristic white mycelial growth of the fungus is visible in the cob and between the kernels.

The disease is caused by the fungus *Nigrospora sphaerica* (Sacc.) Mason (*Basisporium gallarum* Moll.), which is able to live from season to season on old plant parts in and on the soil.

All evidence indicates that vigorously growing plants are highly resistant to infection. The only plants that are subject to attack are those that are mature or have been injured or prematurely killed by other diseases, such as some root rot or stalk rot, or by low temperatures.

Control of this disease can be accomplished to a considerable extent by growing hybrids or varieties adapted to the particular locality. Corn that matures early in relation to the growing season is more susceptible to infection than corn that makes full use of the growing season. On the other hand, late-maturing corn may be injured or killed by low temperatures before the ears are fully mature. Ears on such corn are readily attacked by nigrospora ear rot.

Rhizoctonia Ear Rot

Rhizoctonia ear rot has been reported only from Florida, although it may be present in other neighboring States. In early stages of infection the ears and husks are covered with a salmon-pink mold, which in later stages turns dull gray. The husks are tightly cemented together by the growth of the fungus between them. With the advance of the disease, small brown to dark-brown "knots," or sclerotia, are seen in the mold growth. Unlike some of the other ear rots, the ears seem to be susceptible in the early stages of growth. The general appearance of the rotted ears is much like that of ears infected with *Diplodia zeae*. The disease is caused by the fungus *Rhizoctonia zeae* Voorhees, which lives over in a dormant condition in the form of sclerotia on seed and on plant refuse in the field and in the soil. No control for the disease is known.

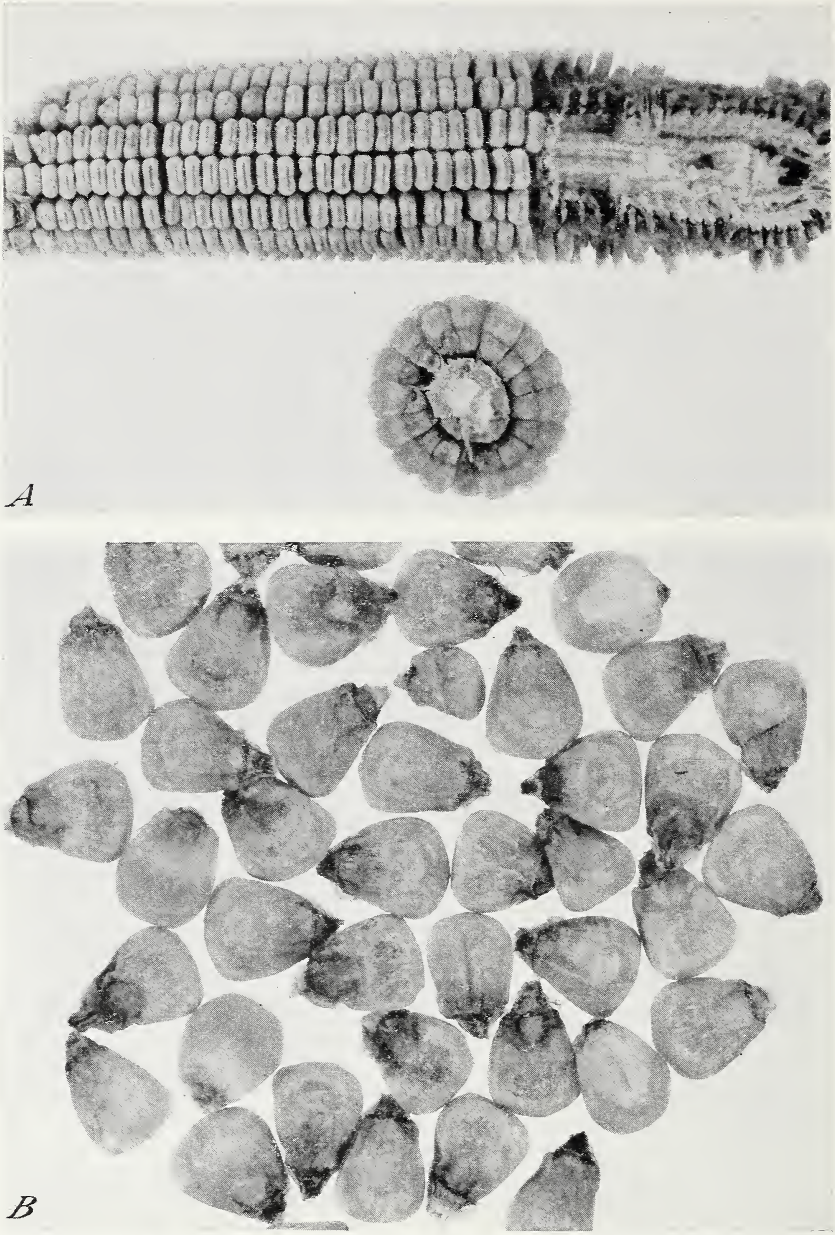

FIGURE 19.—Nigrospora ear rot. *A*, Ear showing symptoms of this ear rot; note chaffy condition, shredding of the cob, and black spore masses at base of kernels and in the cob. *B*, Kernels infected with *Nigrospora sphaerica* (*Basisporium gallarum*). Black specks on faces of kernels are spore masses.

Other Ear Rots

From time to time fungi other than those already described may cause rotting of the ears. These instances are generally localized or infrequent, and their occurrence is most often brought about by unusual environmental conditions. Species of *Penicillium* and *Aspergillus* sometimes cause ear rots.

In very dry years and in the western areas of the Corn Belt penicillium ear rot may be quite abundant. The symptoms are rather distinct; it is characterized by a powdery bluish-green mold over the kernels (fig. 20). Usually the fungus gains entrance through and follows the injuries caused by earworms. Spores of *Penicillium* sp. are illustrated in figure 1, *I*.

Species of *Aspergillus* have been reported as causing appreciable damage on corn ears during some seasons in the southwestern sections of the United States. Infection almost invariably takes place through injuries caused by earworms. The kernels of diseased ears are covered with a yellow or black powdery mold, which is not seen until the ears are husked; it seldom affects the entire ear.

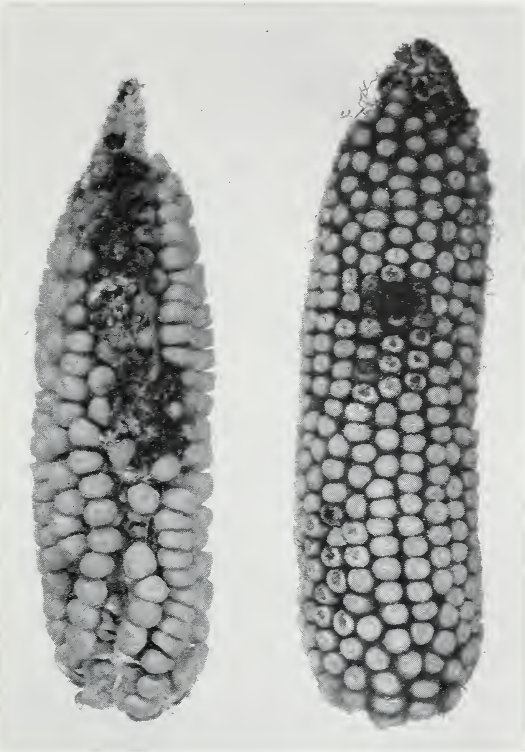

FIGURE 20.—Penicillium ear rot. Infection of the ear at the left was brought in through earworm injury. The rot is bluish green in color and is composed of a powdery mass of spores.

STORAGE DISEASES

Several fungi are known to attack corn after harvesting when the corn has been cribbed or later when it has been shelled. All of the ear rot fungi continue to grow on corn when mild temperatures and sufficient moisture are present. Species of *Aspergillus*, *Penicillium*, and *Fusarium* are able to continue growth and effect rotting in corn after harvest. One rather conspicuous storage rot commonly referred to as "blue eye" is caused by *Penicillium* sp. (fig. 21).

Control of rotting in storage can be accomplished by making certain that shelled corn is thoroughly dry (contains only 14 percent moisture or less) before it is placed in a bin. This is particularly important with corn to be used for seed.

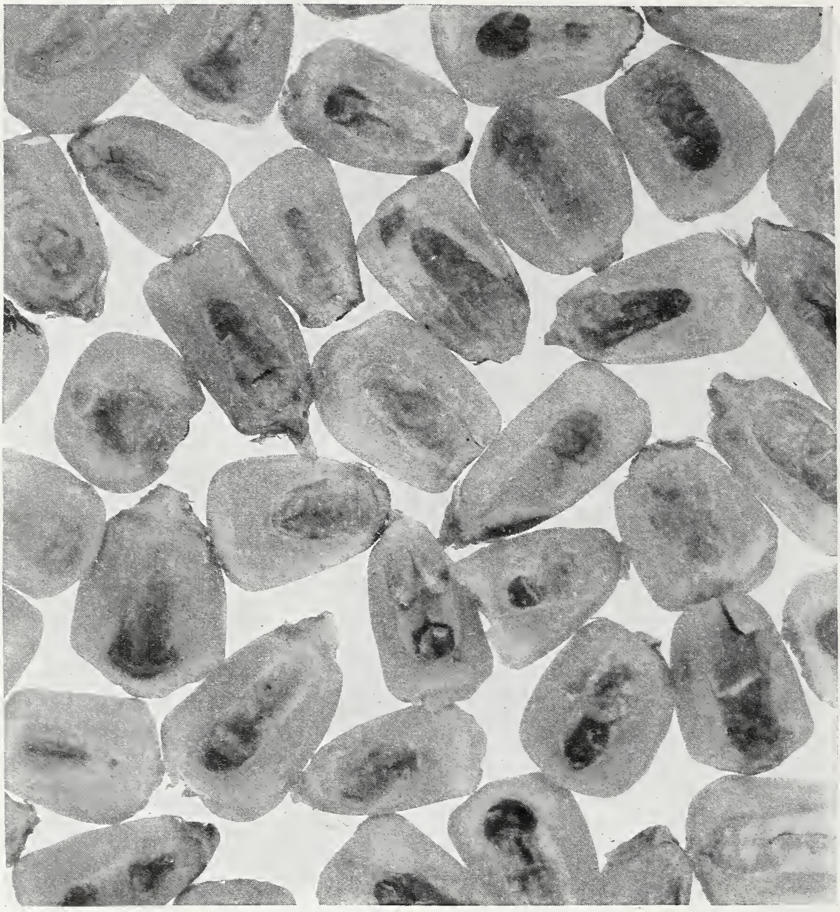

FIGURE 21.—"Blue eye" disease of the kernels. This is a disease that develops in storage when the moisture content of the grain is high and mild temperatures prevail. The embryo, or germ, is completely overrun with the blue-green mold, *Penicillium* sp.

SMUTS OF CORN

Common Smut

Because of its conspicuous nature and widespread occurrence, common smut is perhaps the best known disease of corn. It is to be found throughout the world wherever corn is grown. In some seasons, because of climatic conditions, considerable losses occur.

The disease may attack any above-ground part of the plant (fig. 22). The galls, or swellings, caused by infection by the smut fungus, vary in size from ¼ inch to about 6 inches in diameter. The swellings at first have a silvery-white appearance, but soon the interior is converted into a black, powdery mass, which becomes exposed when the outer membrane of the gall breaks. The black, powdery material

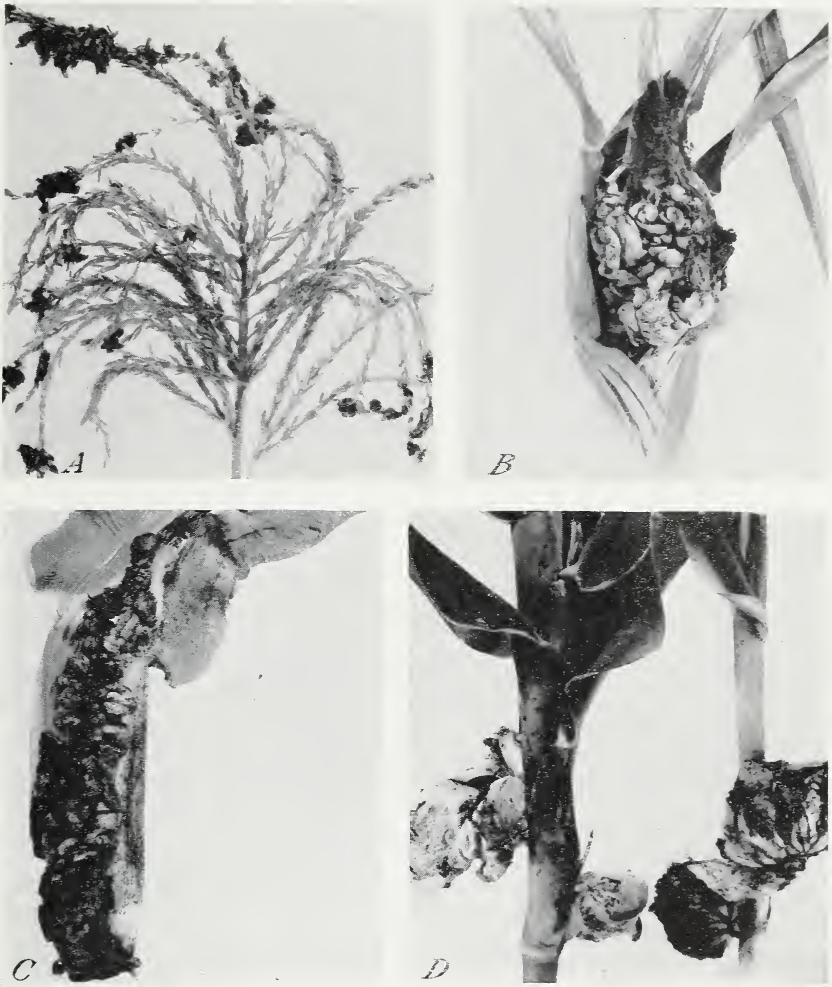

Figure 22.—Common smut of corn: *A*, On tassel; *B*, on ear; *C*, on leaf sheath; and *D*, on stalk.

consists of minute spores of the smut fungus. These spores are carried about by the wind and cause further infection. Small galls under 2 inches in diameter apparently cause little damage to the plant unless they are on the ear. Galls larger than 2 inches in diameter and situated above the ear appear to be more injurious to the plant and often cause barrenness. Infection below the ear, unless the gall is large, does not appear to be as destructive. Ear infections obviously cause greater losses than galls in other parts of the plant.

Common smut is caused by a fungus known as *Ustilago maydis* (DC.) Cda. The powdery mass in the galls is made up of millions of extremely small black spores (fig. 1, *F*, *a*) that serve to spread and propagate the fungus. These spores germinate (fig. 1, *F*, *b*) to cause infection directly or to produce secondary spores, which infect the host.

The black spores from the galls live over in the soil and germinate the following year. The climatic factors affecting the severity of epidemics of smut are not fully understood. The disease is frequently more severe during dry seasons. In the western sections of the Corn Belt, where the growing season is comparatively dry, smut appears to be a more important factor than in the more humid areas.

Late plantings and mechanical injury, such as hail damage, appear to favor the development of smut. Plants growing in soils excessively high in nitrogen and organic matter tend to show more smut.

Control of common smut can best be brought about by using cultural practices that promote steady growth of the crop through the season. Such practices include maintaining well-balanced soil fertility, along with judicious rotation of crops. Choosing hybrids or varieties that are known to have resistance to smut will also tend to lower losses from the disease. This disease is not seed-borne; therefore treatment of the seed with a fungicidal dust is of no avail in controlling it.

HEAD SMUT

Head smut, which attacks the ears and tassels, is of minor importance in the United States except in localized areas in the Southwest and the Pacific Coast States. In the regions where it does occur, however, damage is often very severe.

The young plant is penetrated by spores living on the seed or in the soil. When the plant produces tassels and ears, galls of spore masses are formed at these points, and these organs are destroyed. The membrane of the gall breaks early, discharging the powdery mass of spores, which are disseminated by the wind.

The disease is caused by a fungus known as *Sphacelotheca reiliana* (Kuehn) Clint. The parasite lives over from year to year in the soil and on the seed.

Control of the disease can be accomplished by avoiding replanting in fields where the disease has occurred within the previous 2 years. Unlike common smut, head smut is seed-borne, and consequently seed treatments have been effective in its control, provided the seed is planted in soil free of the fungus spores. The use of strains of corn resistant to this smut also contributes toward control of this disease. Sorghum is attacked by another strain of this same species of fungus. The strain of the fungus from sorghum, however, will not attack corn, nor will the fungus from corn attack sorghum.

OTHER CORN DISEASES

BLACK-BUNDLE DISEASE

Black-bundle disease usually is of minor importance, and the nature of it is not well understood. In some instances, however, rather high percentages of infection have occurred.

Symptoms, which show up usually when the kernels begin to dent, are the development of nubbins, multiple ears at one node, barrenness, and purple discoloration of the plant. In plants showing such symptoms, blackening of the water-conducting vessels of the stalks, or fibrovascular bundles as they are called, usually can be found on splitting the stalk. The disease is reported to be caused by the fungus *Cephalosporium acremonium* Cda. The fungus enters the young seedling, that is, it continues to grow inside the plant. When seed from infected plants is planted, the seedlings may be attacked by the fungus.

No definite control is known for this disease, although rotation is to be recommended as a precautionary measure. Seed treatment does not completely control the disease.

Mosaic Disease

In the United States mosaic occurs only in the vicinity of sugarcane fields infected with the same disease. In some instances the disease may reduce the yield slightly.

Symptoms appear as a mottling or striping of light green surrounded by the normal dark-green tissues. These symptoms are more evident in the younger than in the older leaves. In some instances the symptoms may completely disappear.

The disease is caused by a virus in the juice of the plant and is spread by certain insects, particularly the corn aphid. When these insects feed on infected sugarcane they may later carry the virus to corn.

Control can be obtained through eradicating susceptible wild grass hosts and volunteer cane sprouts.

THE CONTROL OF CORN DISEASES IN GENERAL

There are many factors to be considered in the control of corn diseases. The major diseases are usually not controlled by use of any one measure, but rather by judicious practice of all methods that tend to reduce the diseases to a minimum.

The seed itself should be selected on the basis of high germination and freedom from disease and mechanical abrasions, and it should be fully matured. It may be advisable to treat the seed with some recommended fungicidal dust to insure against seedling diseases. Consideration should be given to proper preparation of the seedbed and proper time of planting. Very early planting, because of the hazard of cold, wet weather, may bring about a high percentage of seedling blight. The building-up and maintenance of a proper fertility balance in the soil is a factor not to be overlooked. Sanitation practices, including clean plowing and proper rotations, are measures that will tend to reduce the sources of disease-producing organisms and should be incorporated in a program to produce healthy corn crops.

The most important aspect in the control of corn diseases is the use of resistant hybrids wherever possible. Wide differences in resistance to some diseases are found among the various inbred lines and hybrids, but toward other diseases very little difference in resistance has been found. Much remains to be done in developing corn hybrids and varieties resistant to certain diseases. Because of the large and increasing number of inbred lines and hybrids used in the United States and because of the variety of environmental conditions under which the corn is grown, it would not be feasible to classify all these lines with respect to their relative resistance to even the more important diseases. Most of the State agricultural experiment stations throughout the country maintain corn-breeding programs, and from these institutions information regarding the relative resistance of lines of corn used in a particular State may be obtained. Corn breeders, agronomists, and plant pathologists at the various State agricultural experiment stations, because of their close acquaintance with the strains of corn used and the prevailing environmental conditions in a particular State, are equipped to make intelligent recommendations regarding the disease resistance of the local inbreds and hybrids.

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